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6. AUTHOR(S)
P. R. Kumar

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of Illinois at Urbana-Champaign
Coordinated Science Laboratory
1308 W. Main Street
Urbana, IL 61801-2307

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13. ABSTRACT *(Maximum 200 words)*

We present the main results obtained by us on the topics of

(i) design of adaptive systems
(ii) analysis of identification, adaptive filtering and adaptive control algorithms
(iii) design and analysis of robustness modifications for adaptive algorithms
(iv) development of simulation software
(v) analysis of simulated annealing
(vi) design and analysis of learning algorithms
(vii) design and analysis of queueing networks and scheduling polices

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PERFORMANCE AND ROBUSTNESS OF SELF-TUNING AND ADAPTATION ALGORITHMS FOR IDENTIFICATION, FILTERING AND CONTROL

FINAL REPORT

P. R. KUMAR

JANUARY 18, 1995

U. S. ARMY RESEARCH OFFICE

DAAL03-91-G-0182

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

4A. Statement of Problem Studied

The main problems studied were the following:

(i) Design of adaptation algorithms for identification, adaptive filtering and control.

(ii) Analysis of the stability, self-optimality, self-tuning, convergence and robustness of adaptation algorithms.

(iii) How to automate the simulation of complex systems such as adaptive control systems.

(iv) Develop a theory of and procedures for learning of functions under noisy observations.

(v) Study the performance of simulated annealing algorithms for optimization.

(vi) Study the problem of designing scheduling policies for queueing networks, which are central in the modeling of communication, computer and manufacturing systems.

(vii) Design of scheduling algorithms.

4B. Summary of the Most Important Results

In [3] we have shown that just parameter projection alone is sufficient to render an adaptive control algorithm robust.

In [4] we have designed algorithms for adaptive active noise cancellation and adaptive feedforward control. We have also established the stability and optimality of these algorithms, which include the long-standing open problem of the output error identification algorithm and adaptive IIR filtering.

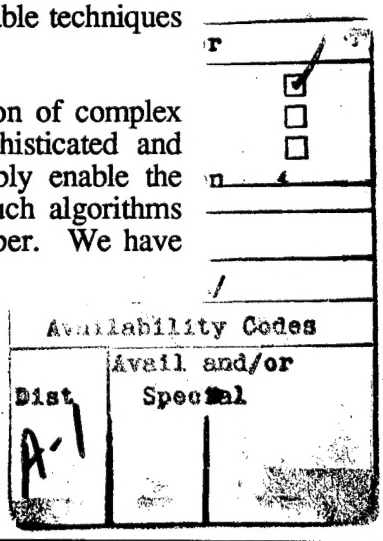
In [6] we have developed robust adaptive controllers for time varying plants, and established their performance.

In [9] we have presented the theory of self-tuning and convergence for linear stochastic systems.

In [14,15] we have developed a new approach to learning functions under noisy data. We have developed and analyzed canonical smooth estimators and learning procedures. These methods provide a new approach to selecting a model of appropriate complexity.

In [1] we have analyzed a new adaptive controller inspired by some recent results in learning from experts. The method of analysis is quite different from available techniques in adaptive control.

In [5] we have developed a new approach to automating the simulation of complex discrete-time systems. The motivation here is that currently many sophisticated and complex control algorithms are being proposed, and it would considerably enable the movement of these algorithms into practice if one could easily test out such algorithms simply by typing in the equations as typically provided in a technical paper. We have developed a software package ISIM which achieves this purpose.



In [22] we have shown that the new class of fluctuation smoothing algorithms developed by us for the efficient scheduling of large re-entrant lines can be regarded as simply trying to alleviated total downstream shortfalls.

In [24] we have proved that these algorithms are stable for reentrant lines in random environments.

In [2] we present our new approach to the stability analysis, performance analysis, and design of queueing networks and scheduling polices. We believe that these results represent a quantum jump in the evolution of the field.

4C. List of All Publications and Technical Reports

1. P. R. Kumar, "An Adaptive Controller Based on Learning form Experts," in *Adaptive Control, Filtering, and Signal Processing*, vol. 74, IMA Volumes in Mathematics and its Applications, K. J. Astrom, G. C. Goodwin, and P. R. Kumar, Editors, Springer-Verlag, New York, 1995, to appear.

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5. R. D. Ellis, R. Ravikanth, and P. R. Kumar, "Automating the Simulation of Complex Discrete Time Control Systems: A Mathematical Framework, Algorithms, and a Software Package," *IEEE Transactions on Automatic Control*, vol. 39, no. 9, pp. 1795-1801, September 1994.

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11. W. J. Aldrich and P. R. Kumar, "Computation of Uniform Recurrence Equations over Finite Domains," submitted to *IEEE Transactions on Automatic Control,* 1993.

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13. J. R. Perkins and P. R. Kumar, "Optimal Control of Pull Manufacturing Systems," submitted to *IEEE Transactions on Automatic Control,* 1994.

14. K. L. Buescher and P. R. Kumar, "Learning by Canonical Smooth Estimation, Part I: Simultaneous Estimation," submitted to *IEEE Transactions on Automatic Control,* 1994.

15. K. L. Buescher and P. R. Kumar, "Learning by Canonical Smooth Estimation, Part II: Learning and Model Complexity," submitted to *IEEE Transactions on Automatic Control,* 1994.

16. H. Jin, J. Ou, and P. R. Kumar, "The Throughput of Closed Queueing Networks: Functional Bounds, Asymptotic Loss, Efficiency, and the Harrison-Wein Conjectures," submitted to *Mathematics of Operations Research*, October 1994.

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26. S. M. Naik, "Robust Adaptive Control and Filtering," Ph.D. Thesis, 1992.

27. B. Madan, " Adaptive Active Noise Cancellation," M.S. Thesis, 1993.

28. J. R. Perkins, "Control of Push and Pull Manufacturing Systems," Ph.D. Thesis, 1993.

4D. List of all Participating Scientific Personnel Showing Any Advanced Degrees Earned by Them While Employed on the Project

Prof. P. Kumar
Mr. Qing Xu
Mr. Sunil Kumar
Mr. Haiming Jin
Dr. Kevin Buescher, Ph.D.
Dr. James Perkins, Ph.D.
Mr. William Aldrich, M.S.
Ms. Barkha Madan, M.S.
Dr. Chi Hung Lu, Ph.D.
Dr. Sanjeev Naik, Ph.D.
Dr. Wei Ren, Ph.D.

5. Report of Inventions

(i) An adaptive active noise cancellation algorithm system.

(ii) An automated simulator for complex discrete time systems.

6. Bibliography

See list in 4C.